10/594717
IAP2 Rec'd PCT/PTO 29 SEP 2006

MODULAR STRUCTURE

FIELD OF THE INVENTION

The present invention relates broadly to a constructional module and a structure including a plurality of constructional modules. The invention further relates generally to a method of construction and relates particularly, though not exclusively, to a method of building construction including roof truss construction.

BACKGROUND OF THE INVENTION

Buildings that can be deployed quickly and efficiently are commonly required for example in military use. Such temporary structures are typically used in establishing a base camp and include buildings for accommodation, workshops, control facilities, amenities and as equipment stores. Further, some buildings are required to have large clear spans in the order of 20m or more to house for example major equipment such as aircraft, and vehicles. As the structures often are located in remote areas and need to be assembled in hostile conditions, there is a continuing need to provide such redeployable structures that can be erected and disassembled more effectively.

Improvements in material technology and construction methodology have allowed large redeployable structures to be transported and erected. Newer technologies such as air-supported structures have evolved but require mechanical equipment, pumps, fuel etc to maintain and are understood not to be well regarded for expeditionary type roles. For larger structures suitable for heavy machinery, aircraft and the like, tent-like solutions do not scale particularly well.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a structure comprising:

a plurality of constructional modules being of a predetermined configuration;

one or more conditioning elements being arranged to cooperate with the constructional modules wherein adjacent of said modules engage one another to form the structure; and

one or more packer elements being adapted to locate between adjacent of the constructional modules to effect reconfiguration of the structure.

Preferably the conditional elements include an upper tendon and a lower tendon being arranged to cooperate with an upper chord member and a lower chord member, respectively, of each of the constructional modules. More preferably the tendons are designed to locate within the hollow section of the lower and upper chord members and stressing of the tendons involves pre-stressing or post tensioning of the tendons and the corresponding chord member.

Preferably the constructional module is shaped in the form of a trapezium including upper and lower substantially parallel chord members being interconnected at opposite ends with respective web members. More preferably each of the constructional modules is of a substantially identical shape. Even more preferably the chord and web members are formed as hollow section members, for example square hollow section (SHS) members. Still more preferably the trapezium-shaped constructional module includes a pair of diagonal web members arranged to add rigidity to the module.

Preferably the constructional module includes interlocking means being arranged to provide interlocking of the adjacent modules. More preferably the interlocking means includes an integral spigot being adapted to engage a hole of an adjacent module, or *vice versa*, and designed to permit pivotal movement between adjacent of said modules on

deployment of the conditioning elements. Even more preferably the spigot or hole allows a hinged action between said adjacent modules. Still more preferably the spigot and/or hole together with the surrounding portion of the constructional module is reinforced. Alternatively the interlocking means at top chord level includes a pivotal or hinged connector such as a clevis/pin type arrangement.

Preferably the constructional module is of a composite construction. More preferably the composite constructional module is fabricated from a fibre composite material such as a particulate filled resin material with high strengths fibre reinforcement, or a polyester resin based material. Alternately the constructional module is formed from a polymeric material and may, for example, be pultruded.

Preferably the structure is a building structure, and in particular a roof truss. More preferably each of the constructional modules is a truss module.

Preferably the roof truss is clad with elongate and transversely oriented sheeting. More preferably the sheeting is of a channel section and fabricated of a rigid material including a plastic such as PVC or ABS, or metallic material. Alternately the cladding is made from a fabric such as canvas.

Preferably the structure is redeployable.

According to a further aspect of the invention there is provided a method of construction, said method including the steps of:

providing a plurality of constructional modules each being of a predetermined configuration, one or more conditioning elements being arranged to cooperate with said modules, and one or more packer elements being adapted to locate between adjacent of the constructional modules;

locating the modules adjacent one another and positioning the conditioning elements to permit engagement of said adjacent modules;

deploying the conditioning elements wherein the modules are together configured to form a structure, the packer elements being arranged to effect reconfiguration of the structure.

Preferably the reconfiguration step is effected prior to deployment of the conditioning elements.

Preferably the conditioning elements are each in the form of tendons and the step of deploying the conditioning elements involves stressing of the tendons. More preferably this involves pre-stressing or post tensioning of the tendons which effects deployment of the structure. Even more preferably the structure is a roof truss and stressing of the tendons provides erection of the roof truss.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to achieve a better understanding of the nature of the present invention a preferred embodiment of a constructional module and a corresponding structure including a plurality of constructional modules together with a method of construction will now be described in some detail, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a roof structure constructed in accordance with an embodiment of the invention;

Figures 2A to 2F show in front elevation a structure, or in this embodiment modular frame, including a plurality of constructional modules which in the case of figure 2B is taken from the roof structure of figure 1 whereas figures 2A, and 2C to 2F depict different sizes of the modular frame;

Figure 3A illustrates in side elevation and part enlarged sectional view one of the constructional modules of the preceding figures;

Figures 3B shows various cross-sectional views of alternate constructional modules;

Figure 4 shows an elevational view of adjacent constructional modules and details pertaining to upper and lower interlocking connection between adjacent modules;

Figures 5A to 5C schematically illustrate sequential erection of the roof truss of for example figure 2B;

Figure 6 shows in elevational and enlarged part perspective view cladding of for example the roof structure of figure 1; and

Figure 7 shows in perspective and sectional views an end wall of the redeployable roof structure of figure 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As best shown in figure 1 there is a building or shelter system 10 comprising a series of structures or in this embodiment modular frames 12A to 12F being arranged generally parallel to and laterally spaced from one another, and interconnected with in this example, roof sheeting designated generally as 14. The modular frames such as 12A are each in their erected condition in the form of a roof truss each including a plurality of constructional modules or in this example truss modules or panels such as 16A and 16B.

As shown in figure 3A each of the truss panels such as 16A is shaped in the form of a trapezium including upper and lower substantially parallel chord members 18 and 20, respectively, which are interconnected at opposite ends with web members 22 and 24. The truss panel 16A also includes a diagonally oriented web member 26 which provides additional rigidity to the truss panel 16A. Alternatively the diagonal web member 26 is one of a pair of diagonal web members which together form an "X". Each of the truss panels such as 16A of this embodiment are of a substantially identical profile shape and constructed of a composite material with the chord and web members being of a hollow section. For example, the lower chord 20 of the truss panel 16A as shown in the detailed sectional view of figure 3 is formed as a square hollow section (SHS) having an internal void 28. Figure 3B illustrates three (3) alternate constructional modules or panels each having solid webs rather than the diagonal web member 26 of the previous embodiment. In order to avoid repetition, and for ease of reference, like components of this embodiment have been designated with an additional "0", for example the truss panel 160.

The composite material from which the constructional modules of this embodiment are formed is a particulate filled resin (PFR) material which permits the truss panels to be cast or moulded. This provides a lightweight and robust material which is relatively easy to manufacture and the PFR has a reduced amount of expensive high strength fibres such as kevlar and carbon fibre but rather relies upon a low cost filler to provide robustness, placement and protection to the fibres somewhat analogous to reinforced concrete where the higher strength steel reinforcement is positioned and protected by the concrete filler.

An alternate technique is for the truss panels such as 16A or other constructional modules to be "pultruded" from a composite material. In this alternate example the module is fabricated from separate sections, each pultruded from a composite material and fixed together.

As shown in figures 2A to 2F the truss panels such as 16A and 16B of this embodiment are of the predetermined trapezium configuration so that on engagement, or in this case abutment, with one another they together form the building structure or module frame such as 12A. In the examples of figures 2A to 2F the modular frame such as 12A is configurable depending on the number and relative positions of the truss panels such as 16A and 16B or other constructional modules. In this embodiment the structure or modular frame such as 12A includes packer elements (not illustrated) located between adjacent truss panels such as 16A and 16B to adapt the modular frame such as 12A for different span, height and pitched roof structures 10. The packer elements are designed to locate in the space between adjacent lower chord members such as 20 of adjacent truss panels such as 16A and 16B to adjust the spacing between modules or panels 16A/B and hence the geometry of the modular frame 12A.

The structure or modular frame 12A of this example also includes conditioning elements arranged to cooperate with the constructional modules or truss panels such as 16A and 16B to form the modular frame 12A. In this case the conditioning elements include tendons which locate within the hollow section of the upper and/or lower chord member 18 or 20 of adjacent and abutting truss panels such as 16A and 16B. This is best illustrated in figure 4 where the conditioning element or lower tendon 28 passes through adjacent lower chord members 20A and 20B of adjacent and abutting truss panels 16A to 16C. This illustration also shows an exemplary packer element 29 to be located between adjacent of the truss panels such as 16A and corresponding lower chords 20A and 20B. As will later be described in more detail, the conditioning means or lower tendon 28 is deployed or in this example stressed or tensioned to facilitate cooperative movement of the truss panels such as 16A and 16B and as such erection of the modular frame 12A.

The adjacent constructional modules or truss panels 16A and 16B each include interlocking means arranged to provide interlocking of the panels 16A and 16B when in this example they are in abutting engagement. The interlocking means in this construction of the constructional modules includes a protrusion or integral spigot such as 30A and 30B located at adjacent ends of the upper and lower chord members 18 and 20, respectively.

An opposite end of each of the upper and lower chord members 18 and 20 includes a respective hole 32A and 32B which interlocks with the spigots of the adjacent constructional module or truss panel (see figures 3A and 4). This spigot/hole connection permits pivotal movement between adjacent of the modules or truss panels such as 16A and 16B which on erection of the modular frame 12A provides a hinged action at this connection or abutment of the upper chord members such as 18. The constructional module or truss panels are preferentially reinforced about the surrounding portion of the spigot and recess such as 30A and 32A. Alternately, the connection between the modules or truss panels at top chord level is provided by a pivotal or hinged connector. This connector (not shown) may be in the form of a clevis/pin type arrangement.

As best shown in figure 6 the roof structure 10 is clad with elongate and transversely oriented sheeting being of a trough or channel configuration such as 34A to 34F. The roof cladding of this embodiment is fabricated from a rigid plastic material such as PVC or ABS. The roof cladding 34A is substantially half the width of the top chord member such as 18 and of a sufficient length to extend between adjacent modular frames such as 12A and 12B with a butted or lapped connection between the cladding. Adjacent of the roof cladding panels such as 34A and 34B are connected to one another so as to provide a connection which permits hinging action during erection of the modular frame such as 12A. The roof structure 10 may also be lined with a flexible membrane 36 such as a canvas membrane which seals the cladding 34A to 34C from water and dust. The roof structure 10 may also include an insulation or ballistics board 38 which underlies the flexible membrane 36 and sits across the roof cladding such as 34B. In an alternate construction the roof cladding may include a flexible membrane alone such as a fabric covering for example canvas.

As shown in figure 7 there is an end wall designated generally as 40 formed in this example from wall panels of an identical construction to the roof cladding panels such as 34A. The wall panels such as 42A and 42B are, in a similar fashion to the roof cladding panels, of a standard length, such as 6 metres. The wall panels span vertically from ground level to the roof line, and the roof cladding panel overhang together with purpose shaped infills provide some measure of closure to the building. At ground the wall panels may be set in a trench and backfilled to provide support, and the depth of embedment allows for

effective adjustment of length of the wall panels. Walls panels may also be lapped if the standard length is insufficient to vertically span from ground to the roof line. A door opening such as 44 can be supported via a bolted lintel 46.

The roof structure 10 is particularly well suited to applications where it can be redeployed. These applications include but are not limited to deployable hangars for the various military forces and ideally are suited to roof structures having spans of up to around 35 metres but more often around 15 metres. Redeployable and modular roof structures such as those described in the preceding paragraphs are well suited to these applications where deployment considerations are transportation, relatively fast set up and disassembly.

The general steps involved in constructing the roof structure 10 of the preceding example are as follows:

1. as best shown in figure 5A, the constructional modules or truss elements such as 12A are located alongside one another in a collapsed or flat condition together with the conditioning means or lower tendon 28 threaded through lower chord members such as 20A and 20B;

2. as further shown in figure 5A, the roof structure 10 includes an adjustable support module such as 48A and 50A located at respective opposing ends of the modular frame 12A with one of the support panels such as 48A being anchored;

3. as best shown in figure 5B, the conditioning means or tendon 28 is deployed or tensioned wherein the constructional modules or in this example trapezium-shaped truss panels are hinged relative to one another whereupon the modular frame 12A is progressively raised whilst the other adjustable support panel 50A slides inwardly toward the anchored support panel 48A; and

4. as best shown in figure 5C, the modular frame or truss structure 12A is progressively moving to its erected condition with the adjacent constructional modules or truss panels such as 16A and 16B of this example abutting one another whereupon the floating support panel 50A is anchored.

This mode of construction enables the modular frame to move from its collapsed condition to its erected condition largely as a function of the geometry of the constructional modules and their mode of connection in conjunction with the conditioning means or in this example the tendons such as 28. The trapezium-shaped truss panels such as 16A and 16B have a shorter lower chord member 20 than the upper chord member 18, and the outer web members 22 and 24 taper toward one another so that each constructional module or truss panel such as 18A has mutually inclined outer side bearing surfaces. It will be appreciated that the respective outer bearing surfaces of the truss panels such as 16A and 16B in the collapsed condition are spaced apart except at their upper portion whereas on erection of the modular frame such as 12A the bearing surfaces are substantially in abutment with one another. However, as will be appreciated from figures 2A to 2F the spacer elements may be utilised to vary this degree of abutment and thus the configuration of the structure or modular frame such as 12A.

Without wanting to be limited by shapes and/or dimension, the following table provides sizes for the roof trusses of figures 2A to 2F. The thickness of the spacer elements or packers located between adjacent modules or truss panels such as 16A and 16B are also given.

Modular Frame	**Width (m)**	**Height (m)**	**Packer thickness (mm)**	**No. of truss panels**
Figure 2A	35.23	11.112	No packer	32
Figure 2B	19.669	8.5	No packer	20
Figure 2C	35.189	12.5	80	32
Figure 2D	53.05	15.0	120	44
Figure 2E	30.714	9.0	80	26
Figure 2F	38.643	10.0	100	30

Now that a preferred embodiment of the present invention has been described in some detail, it will be apparent to those skilled in the art that at least the preferred embodiment of the constructional module/structure and method of construction have at least the following advantages:

1. The constructional modules are relatively compact and lightweight and as such lend themselves to redeployable structures;

2. The structure being of a modular design can be erected with relative ease requiring minimal tools and trade skills;

3. The structure is reconfigurable by varying the relative positions of the constructional modules, using a different number of modules, and/or varying the deployment of the conditioning elements;

4. The structure can be adapted for differing conditions and for example include additional conditioning elements in the form of tendons arranged along the upper chord of for example the truss frame;

5. The structure can be assembled at ground level and then erected using the conditioning elements which for example are tensioned, and as such this method of deployment minimises safety requirements for working at heights;

6. The structure and associated building system provides a relatively large clear span roofing system;

7. The structure and constructional modules have a minimum number of loose components but rather include "captive" components which avoid loss in adverse conditions;

8. The constructional modules of the structure permit compact storage and transportation, for example the modules may be fully containerised in standard freight containers transported by air, road, rail or sea; and

9. The structure is formed largely from components which are identical and as such there are a minimum number of components to handle and inventorize, and it is easier and more manageable to have spares.

Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. For example, the constructional modules may be shaped differently to the trapezium-shaped truss panels of the described embodiment. The panels need not be limited to a composite construction but for example they extend to other preferably lightweight materials such as aluminium alloy, or alternatively steel. Similarly, the roof cladding may be constructed of any suitable material although high pressure thermoformed (HPT) plastics such as PVC are preferred. The building structure may in military applications include passive or active means to reduce the radar signature of the redeployable structure and any contained equipment. Ideally, the shelter system materials will provide a minimised radar signature and it is expected that special coverings may be able to actively shield the internal equipment. Otherwise, it is preferable that the structure or in the described embodiment redeployable building system includes environmental conditioning systems (heating/cooling) and ventilation, is capable of chemical agent decontamination using standard procedures when erected, can provide blackout capability, and/or provides camouflage capability. The structure need not be limited to the roof truss described but may for example extend to bridges and other structures.

All such variations and modifications are to be considered within the scope of the present invention, the nature of which is to be determined from the foregoing description.